

MULTIFREQUENCY OBSERVATIONS OF THE BLAZAR 3C 279 IN JANUARY 2006

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ABSTRACT

We report first results of a multifrequency campaign from radio to hard X-ray energies of the prominent γ -ray blazar 3C 279, which was organised around an INTEGRAL ToO observation in January 2006, and triggered on its optical state. The variable blazar was observed at an intermediate optical state, and a well-covered multifrequency spectrum from radio to hard X-ray energies could be derived. The SED shows the typical two-hump shape, the signature of non-thermal synchrotron and inverse-Compton (IC) emission from a relativistic jet. By the significant exposure times of INTEGRAL and Chandra, the IC spectrum (0.3 - 100 keV) was most accurately measured, showing – for the first time – a possible bending. A comparison of this 2006 SED to the one observed in 2003, also centered on an INTEGRAL observation, during an optical low-state, reveals the surprising fact that – despite a significant change at the high-energy synchrotron emission (near-IR/optical/UV) – the rest of the SED remains unchanged. In particular, the low-energy IC emission (X- and hard X-ray energies) remains the same as in 2003, proving that the two emission components do not vary simultaneously, and provides strong constraints on the modelling of the overall emission of 3C 279.

Key words: X-rays: observations - galaxies: active - galaxies: quasars: individual: 3C 279.

1. INTRODUCTION

The discovery by the experiments aboard the Compton Gamma-Ray Observatory (CGRO) that blazars can radiate a large – sometimes even the major – fraction of their

luminosity at γ -ray energies marked a milestone in our knowledge on blazars. During the CGRO mission about 90 blazars were detected by the different CGRO experiments at γ -ray energies, the majority by the EGRET experiment at energies above ~ 100 MeV [2]. 3C 279, an optically violently variable (OVV) quasar located at a redshift of 0.538, is one of the most prominent representatives of these sources. The source shows rapid variability in all wavelength bands, polarized emission in radio and optical, superluminal motion, and a compact radio core with a flat radio spectrum. These properties put the quasar 3C 279 into the blazar sub-class of AGN. According to the unified model of Active Galactic Nuclei (AGN), blazars are sources which expel jets close to our line-of-sight.

3C 279 was already detected by INTEGRAL in June 2003 [1]. Those high-energy observations were supplemented in X-rays by a short (5 ksec) Chandra pointing, and by ground based monitoring from radio to optical bands. Since the blazar was found in 2003 at the faintest optical brightness (optical R-band: ~ 17 mag) of the last 10 years, roughly 5 mag fainter than the maximum, and about 2.5 to 3 mag fainter than average, a simultaneous spectral energy distribution (SED) of an exceptional optical low-state could be compiled [1]. In order to measure emission changes as function of optical brightness, we proposed for an INTEGRAL ToO observation during an optical high state (criterion: optical R-band brighter than 14.5 mag). In January 2006, the trigger criterion was met, and the INTEGRAL observations together with supplementing multifrequency observations were carried out. This campaign resulted in a well covered SED from radio to hard X-ray energies.

In this paper we present first results of this 2006 multi-wavelength campaign on 3C 279. Because of the page restrictions, we concentrate on presenting the main ob-

servational results, focussing on the observed SED and its comparison to the one of 2003. A more detailed presentation, including a discussion on the scientific implications of the new results, will be given in a later paper (Collmar et al., in prep.; including also all participating individual WEBT (Whole Earth Blazar Telescope) collaborators in the author list). In addition, the results on variability analyses and time correlations of the different wavelength bands will be given elsewhere (Böttcher et al., in prep.).

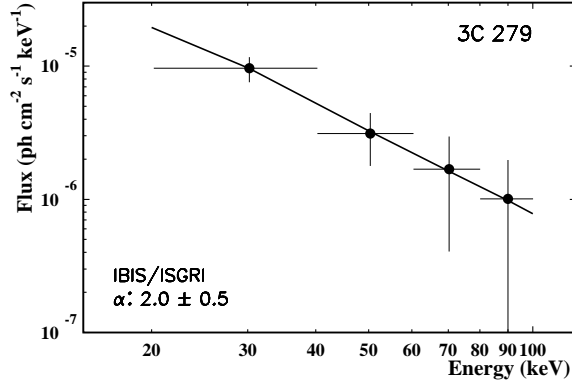
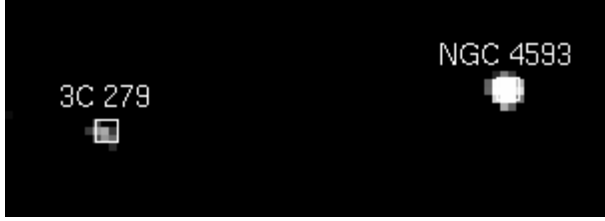


Figure 1. Top: The ISGRI image shows a 6.4σ detection of 3C 279 in the 20-60 keV band. In addition, the Seyfert galaxy NGC 4593 is even more clearly detected. Bottom: The ISGRI hard X-ray spectrum between 20 and 100 keV is shown, together with the best-fit power-law shape.

2. OBSERVATIONS

After the trigger criterion, 3C 279 brighter in the optical R-band than 14.5 mag, was met in early January 2006, we requested the granted ToO observations with INTEGRAL and Chandra. These INTEGRAL observations were carried out for a total of 511 ks between January 13 and 22, 2006 in several pointings, and the Chandra observations on January 17, 2006 for 30 ks. Centered on these high-energy observations, we started a multifrequency campaign, by initiating simultaneous measurements in radio and mm-bands (Effelsberg and Metsähovi radio telescopes, IRAM (Plateau de Bure and Pico Veleta), and the Smithsonian Submillimeter Array at Mauna Kea), in near-IR and optical bands by a WEBT campaign, and additional high-energy coverage (UV, X-rays) by Swift. This campaign resulted in a wealth of data, which – although not all have been reduced and analysed yet – yielded a well-covered SED of 3C 279 from radio to

hard X-ray energies. In particular, by the participation of satellite experiments Swift, Chandra, and INTEGRAL, all with significant exposure times, the best-ever spectral coverage in UV-, X-ray -, and hard X-ray energies was derived.

The data analysis revealed, that 3C 279 was observed during an intermediate optical state. With an R-band magnitude of about 15 mag, the source was ~ 2 mag brighter than during the low-state observations in the 2003 campaign.

3. RESULTS

3.1. High-Energy Observations

The IBIS/ISGRI experiment aboard INTEGRAL detected the blazar at energies between 20 and 100 keV with a significance of $\sim 7.5\sigma$ during the total 511 ks observation. The ISGRI image (Fig. 1) of the 20-60 keV band shows a 6.4σ detection of 3C 279. Other Virgo region sources are also detected in these observations, like the prominent quasar 3C 273 and the Seyfert galaxy NGC 4593 for example. The blazar was measured by ISGRI at a surprisingly low flux level of $(2.53 \pm 0.52) \times 10^{-4} \text{ ph cm}^{-2} \text{s}^{-1}$. Spectral analysis between 20 and 100 keV, assuming a power-law shape, yields a weakly determined average spectral shape (Fig. 1) of photon index 2.0 ± 0.5 (1σ). Due to annealing, no INTEGRAL SPI data are available. JEM-X did not detect 3C 279. Upper limits were derived for two energy bands (5-10 and 10-20 keV) based on the mosaic images from these observations.

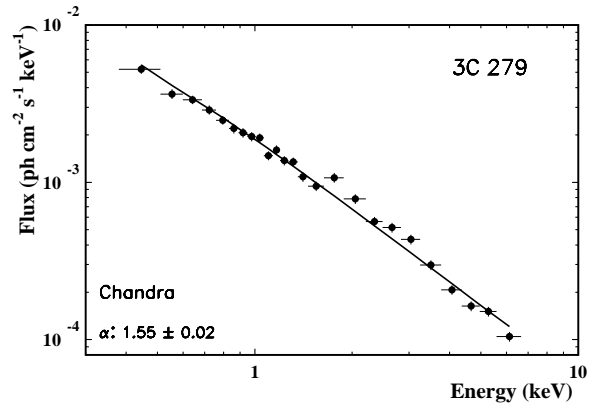


Figure 2. The Chandra 0.3 - 7 keV X-ray spectrum is shown, together with the best-fit power-law shape.

Chandra observed the blazar within the INTEGRAL observational period and simultaneously to INTEGRAL. To avoid pile-up in the Chandra detectors of the assumed strong X-ray source, the LETG-ACIS-S mode was used. 3C 279 is significantly detected by Chandra, and a well-determined X-ray spectrum between 0.3 and 7 keV could

be measured (Fig. 2). Assuming the canonical power-law shape at X-ray energies, a spectral photon index of 1.55 ± 0.02 was derived. The spectral analysis however, indicates a trend for a spectral bending from a harder to a softer spectrum towards higher energies. In particular, no soft excess was found, which would have indicated a contribution of the synchrotron component to the soft X-ray emission. Chandra did not observe any variability of 3C 279 during the uninterrupted source pointing of ~ 8 hours.

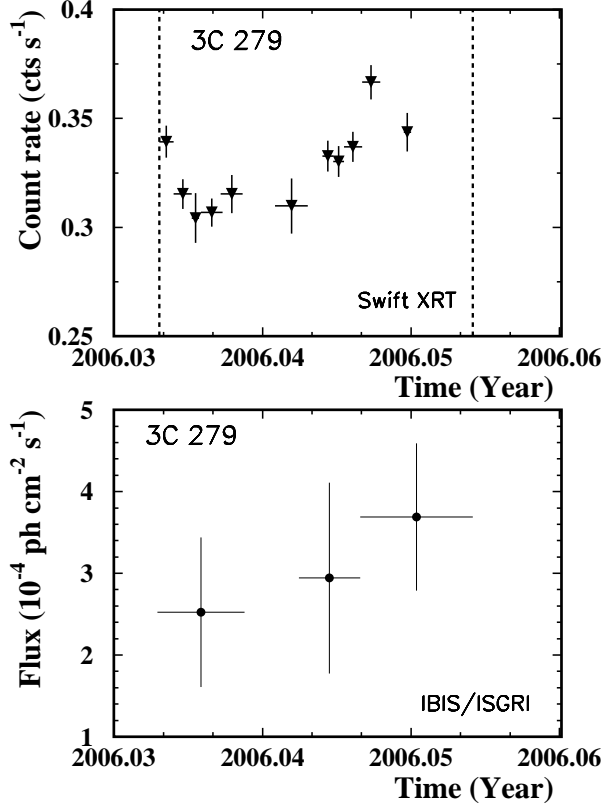


Figure 3. The variability at X-ray (top: Swift/XRT 0.2–10 keV) and hard X-ray (bottom: INTEGRAL/ISGRI: 20–60 keV) energies of 3C 279 during the campaign. The dashed lines indicate the INTEGRAL observational period.

These high-energy INTEGRAL and Chandra observations were valuably supplemented by a series of Swift pointings towards 3C 279. Between January 13 and 20, 2006, Swift observed the blazar regularly, thereby providing important additional information on the source, like an X-ray light curve as measured by the XRT, and the UV fluxes as measured by the UVOT. The Swift XRT (0.2–10 keV) X-ray light curve, together with the IBIS/ISGRI (20–60 keV) hard X-ray light curve is shown in Fig. 3. While Swift observed significant flux variability in X-rays, which can be utilized for correlations studies to other bands, ISGRI – measuring with less statistical significance – can not detect significant variability, although there is a possible trend for a brightening towards the

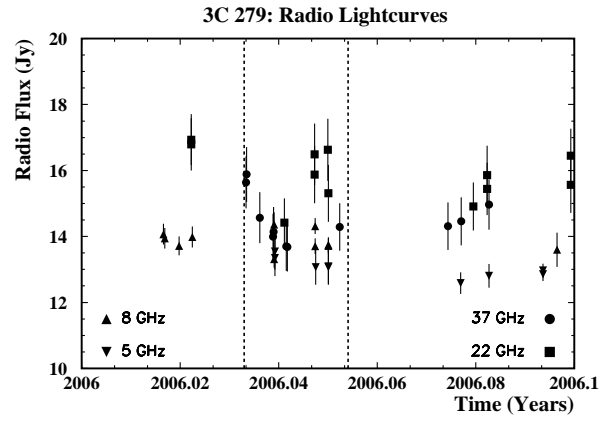


Figure 4. Radio light curves from monitoring observations at or around the INTEGRAL observational period, which is indicated by the vertical dashed lines.

end of its observational period. The Swift XRT spectra of individual pointings agree completely in spectral index with the one measured by Chandra. The Swift UV measurements provided additional coverage of the SED (Fig. 6).

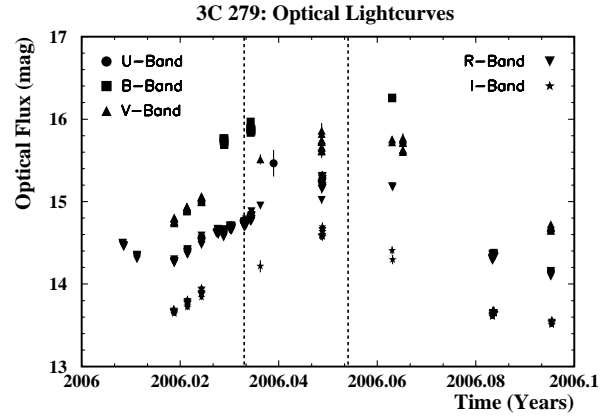


Figure 5. Optical monitoring by the WEBT-campaign at or around the high-energy INTEGRAL observations, indicated by the vertical dashed lines.

3.2. Low-Energy Observations

Since the start of INTEGRAL AO-3, 3C 279 was regularly observed in the optical – in particular during visibility periods of INTEGRAL – in order to keep track of its brightness state. Early January 2006, the blazar exceeded the trigger level for the satellite observations, which then were initiated. In order to have good ground-based coverage, a WEBT campaign was requested simultaneous to the high-energy observations. This campaign resulted in broadband (radio to optical) ground-based monitoring of the blazar. Subsequently light curves (for correlation studies) and average flux measurements (SED) in different wavelength bands could be compiled. The optical

monitoring revealed, that in the R-band the blazar brightened early January up to ~ 14.2 mag on January 5, and then continuously faded during the next 3 weeks, being at ~ 14.7 mag at the beginning and ~ 15.2 mag at the end of the INTEGRAL observations. This may indicate a continuous cooling following an optical flare. The radio and optical light curves of the campaign are given in Figs. 4 and 5. In this page-limited proceedings paper, we shall concentrate on the measured SED. A more detailed analysis of the broadband variability, including inter-band cross correlations and their physical interpretation will be presented in a forthcoming paper.

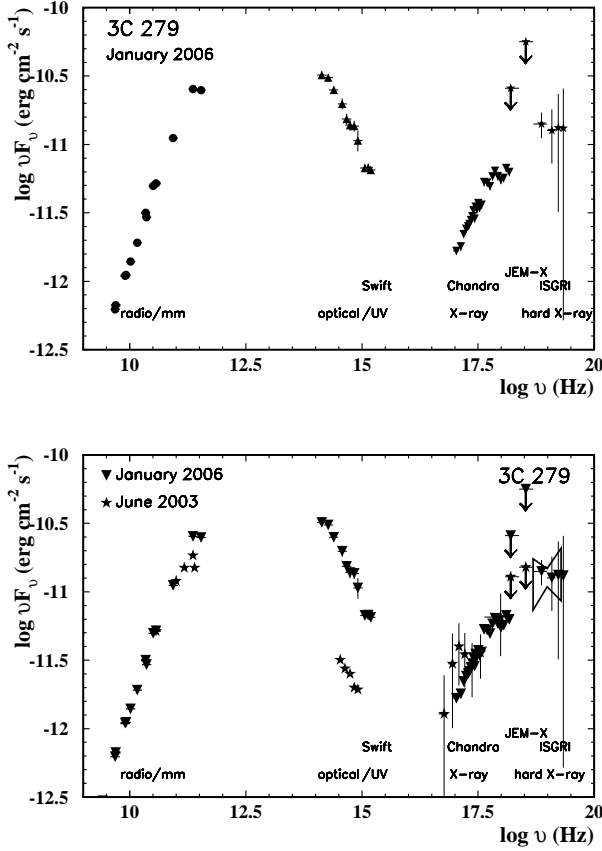


Figure 6. Top: The 3C 279 SED as measured during this campaign in January 2006. The spectrum, well covered from radio to hard X-ray energies, shows the typical two-hump shape, with an unobserved crossover between UV (measured by the Swift UVOT) and soft X-rays (0.3 keV). Flux points are shown with 1σ error bars. Upper limits are 2σ . At low energies the error bars are smaller than the symbols.

Bottom: Comparison of the January 2006 (intermediate optical state) multiwavelength spectrum to the low-state multifrequency spectrum of June 2003 [1]. While the high-energy part of the synchrotron peak (near-IR, optical, UV) is significantly different, the observed low-energy (0.3 - 100 keV) part of the IC peak is unchanged.

3.3. Multiwavelength Results

Fig. 6 (top) shows the contemporaneous SED of 3C 279 during January 2006. The SED, although not strictly simultaneous, is compiled only from data, measured within the INTEGRAL observational period. For example, the IBIS/ISGRI spectrum is averaged over the complete INTEGRAL period, while the Chandra spectrum is – of course – from the 8-hour observation on January 17. The SED is well covered from radio to hard X-ray energies and shows the typical two-hump shape, which is believed to be synchrotron at the lower- and IC emission at the higher energies. The synchrotron peak, located probably somewhere at IR energies, is not observed. The crossover point of the synchrotron and IC emissions is also not observed, because Chandra did not find an excess at soft X-rays, which are already located at the rising IC branch. The SED indicates a deep minimum between the two branches. The significant exposures of Chandra and ISGRI yielded the yet most accurate spectral shape measurement of the rising IC emission of 3C 279. A spectral bending from a harder towards a softer spectrum is indicated. A modelling of this spectrum by assuming a leptonic emission model is in progress (Collmar et al., in prep.).

In Fig. 6 (bottom), this January 2006 SED is compared to the optical low-state one as measured in June 2003 [1]. The observations in 2006 were selected such (ToO) that the blazar was significantly brighter in the optical than in 2003. The goal was to observe how the SED changes with a changing optical flux. The surprising result is, that despite a significant change in near-IR, optical, and UV (the high-energy part of the synchrotron emission), the rest of the SED is unchanged. In particular, the low-energy part (0.3 - ~ 100 keV) of the IC emission remains completely unchanged. This result shows that there is no – at least not simultaneous – correlation between these two bands. Whether the excess synchrotron photons have a counterpart at higher IC energies (MeV, GeV energies) and/or whether energy-dependent time delays occur during the cooling off of a flare, e.g. higher-energy photons are emitted earlier than lower-energy ones, cannot be resolved by this SED comparison. Detailed inter-band variability studies (possible by the wealth of data), and another such measurement during the upcoming GLAST era, when also the MeV/GeV part of the IC emission will be observed, will shed light on these possibilities.

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